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Publication date:
2013

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Löwe, R., Vezzaro, L., Grum, M., Mikkelsen, P. S., & Madsen, H. (2013). *Stochastic runoff forecasting and real time control of urban drainage systems*. Abstract from 7th Annual Meeting of the Danish Water Research and Innovation Platform, Kgs. Lyngby, Denmark. http://www.forskningsplatformen-vand.dk/Documents/Annual%20meeting%202013/Presentations/Session%206/Roland%20Lowe_Presentation_DWRIP_FINAL.pdf

Stochastic runoff forecasting and real time control of urban drainage systems

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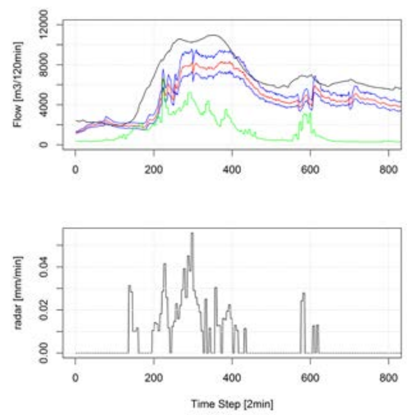
Abstract

Real time control (RTC) is an efficient means to optimise the operation of urban drainage systems and minimize combined sewer overflows. Control approaches range from rule-based strategies, based on past experience of the system, to online global optimization of storage volumes to global forecast based optimization approaches. Commonly used RTC approaches are based on the current measurements, i.e. the system is optimized based on the actual volumes stored in the drainage system.

The ability of predicting the future evolution of rainfall and the generated runoff volumes can further improve the performance of urban drainage systems: water storage in the system can in fact be optimized by both using information on the present situation and the expected evolution in the near future. However, both rainfall and runoff nowcasting models are affected by several sources of uncertainty. For example, radar-based rainfall observations and nowcasting are highly uncertain, and this subsequently affects the results of rainfall-runoff models. This high level of uncertainty has represented an important impediment towards a wide application of rainfall-runoff model in RTC systems. This obstacle can be overcome by quantifying the level of uncertainty in the runoff predictions and by using this information within the RTC strategy.

In this context, we introduce a control framework for urban drainage systems that uses probabilistic runoff predictions in conjunction with current observations to optimize urban drainage systems. The used control strategy is based on the so-called dynamic overflow risk assessment (DORA), an integrated approach which aims to reduce the overflow risk in the controlled drainage system. The overflow risk is calculated by using information on (i) the current water storage in the system, (ii) the expected runoff volume and (iii) the uncertainty of this estimation. The last two data are provided by probabilistic rainfall-runoff models.

These models are based on the so-called stochastic greybox models, which use radar rainfall nowcasts as input and provide runoff predictions (along with uncertainty bounds) for every controlled point of the system as output. A conceptual model in the form of a reservoir cascade is applied to describe the rainfall-runoff relationship in each sub catchment. Other than in the deterministic case, however, the greybox models include a stochastic term that permits the explicit modelling of uncertainties resulting from structural deficiencies, input uncertainties and observation errors. Further, the models can be updated through an extended Kalman filter, which makes them adaptive to current observations and allows accounting for deficiencies in the models' description of the actual situation.



The developed control framework was tested in the Lynetten catchment, located in the centre of Copenhagen. An integrated control of the catchment, based on DORA, is currently in the implementation phase in the system. This current implementation uses a deterministic rainfall-runoff model and it assumes a fixed level of uncertainty on runoff predictions. The performance of the current implementation (evaluated based on the overflow volume) was compared against the proposed framework, where the uncertainty in runoff predictions is dynamically estimated by grey-box models. Preliminary results, based on a small number of sample rain events, illustrate the potential of using probabilistic runoff forecasts in RTC strategies. Additional developments in the greybox model structure and adaptivity will further boost their ability in reducing the uncertainty of runoff estimation and thus improve the optimization of urban drainage systems.

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